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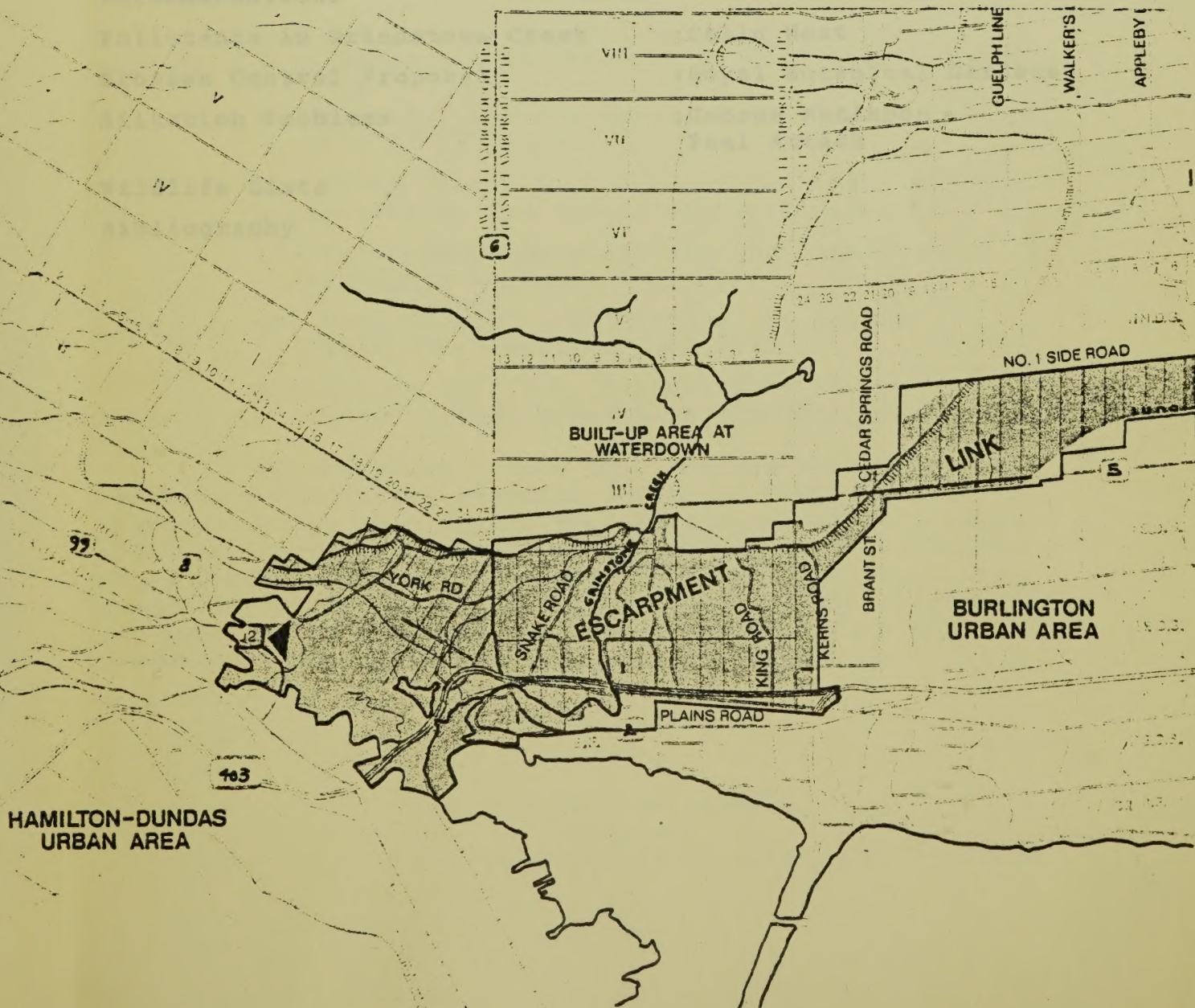
L GRINDSTONE CREEK

INTERIM REPORT ON
POLLUTION & EROSION CONTROL

GRINDSTONE
CREEK

An Interim Report
on
Pollution and Erosion Control
in Grindstone Creek between
Waterdown and Burlington Bay

MARCH 1977



THE GRINDSTONE CREEK SUB-COMMITTEE

City Hall
Hamilton

Aldermen Donald Gray
Chairman
Barbara Capelton
City Hall
Hamilton

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As described in the Introduction to the Report, the area under review involved a mass of recommendations. Inasmuch as the main reason for the sub-committee's being concerned the quality of the water flowing from the Grindstone Creek into the Hamilton Harbour, we trust that the co-ordinating of the Creek across political jurisdictions will not hold up the carrying out of the sampling programme recommended in the Report.

Yours truly,

William Stinson
Chairman

GRINDSTONE CREEK SUB-COMMITTEE

THE GRINDSTONE CREEK SUB-COMMITTEE

City Hall
Hamilton

Alderman Donald Gray
Chairman
Harbour Committee
City Hall
Hamilton

Dear Alderman Gray:

I have pleasure in presenting the Interim Report of the Grindstone Creek Sub-Committee, of which I have the honour to be Chairman.

I would like to express my gratitude for the willing and friendly co-operation of my colleagues, namely

Alderman William O'Connell, Representing the
City of Burlington

Mr. Frank Milne, Representing The Board of
Governors, The Royal Botanical Gardens

Mr. Colin West, Representing the Hamilton-
Wentworth Regional Laboratory

Mr. Paul Attack, Representing the Halton
Region Conservation Authority

Mr. George McKibbin, Representing the
Halton Region Conservation Authority

As described in the Introduction to the Report, the area under review involved a maze of boundaries. Inasmuch as the main reason for the Sub-Committee's being concerns the quality of the water flowing from the Grindstone Creek into the Hamilton Harbour, we trust that the meandering of the Creek across political jurisdictions will not hold up the carrying out of the sampling programme recommended in the Report.

Yours truly,

Gillian Simmons
Chairman
GRINDSTONE CREEK SUB-COMMITTEE

F O R E W A R D

The Grindstone Creek is not a respecter of political boundaries, for all that it lies within the jurisdiction of the Halton Region Conservation Authority. Its west branch rises in Wentworth County, its east Branch in Halton County: they join in Wentworth, flow through Waterdown and over the Niagara Escarpment, passing back into Halton to flow into Wentworth County once more when the waters of Grindstone Creek join those of Hamilton Harbour.

According to the Halton-Wentworth Waterfront Study of 1974+: "Grindstone Bay, its marshes, and Carroll's Point, have excellent potential for passive waterfront recreation activities (such as) fishing, quiet boating, picnics, nature trails, and skating. This area also supports breeding waterfowl, but the marsh is currently filling with sediments which may eventually upset the biological balance of the marsh and endanger its breeding potential. The situation at the mouth of Grindstone Creek is reducing the wildlife potential of Grindstone Bay and marsh areas: more stringent controls are required over upstream development projects".

After due consideration of the above, the City of Hamilton's Harbour Advisory Committee (Alderman Don Gray, Chairman, Controller R. M. Morrow, Aldermen Dennis Carson, Pat Ford, Mr. William Powell, Mrs. Gil Simmons) in 1975 proposed the setting up of a Grindstone Creek liaison committee: this was felt necessary for the following reasons:

- the said Creek drains into Hamilton Harbour

- the Committee was concerned that waters entering the Harbour should be of suitable quality
- the Creek's course crosses political boundaries (i.e., the Regions of Halton and Hamilton-Wentworth).

Subsequently, the following Committee was established:

From the City of Burlington	Alderman William O'Connell
From the Royal Botanical Gardens Board of Governors	Mr. Frank Milne
From the Hamilton Harbour Advisory Committee	Mrs. Gil Simmons (Chairman)
together with the following technical representatives	
From the Hamilton-Wentworth Regional Laboratory	Mr. Colin West
From the Hamilton Region Conservation Authority	Mr. George McKibbin
From the Halton Region Conservation Authority	Mr. Paul Attack

The Grindstone Creek Committee met during 1975 and 1976, and Minutes of these meeting are on file with Hamilton's City Clerk.

The Committee felt above all that these questions had to be answered:

Is there pollution?

Is there erosion?

If so, where, and from what source?

What are the remedies?

Fact-finding has been, therefore, a major activity of the Committee, and recognition should be given to the help received at the outset from Mr. Hall of the Halton Region Planning Department, and from Mr. Afsar and Mr. Taylor of the Hamilton-Wentworth Planning Department: without their guidance in putting the Grindstone Creek in its planning context, the

Committee could not have proceeded. With this assistance, the Committee was able to move forward and decided that examination should be made of the lower reaches of the Creek, as outlined in this Interim Report, and a second Report, to be issued at a later date, would be the result of an examination of the upper reaches, whose surroundings are largely agricultural in character.

This Interim Report consists of the outline of a project proposed by the Committee to the Royal Botanical Gardens, 2 technical sections on pollution and erosion, with recommendations, wildlife lists, and a bibliography.

In discussing erosion control, the Committee was concerned at the high cost of contemporary structural methods compared with vegetative methods which in certain locations are very much cheaper and most effective. It is the Committee's feeling that the Royal Botanical Gardens, in co-operation with the Halton Conservation Authority, would be giving valuable leadership in an area where individual owners of creek-side land will be glad to follow.

Finally, the Committee, well aware of the jurisdictional complexities through which the Grindstone Creek flows, is also deeply conscious of the value of this interesting and largely unspoiled watercourse to the residents of both Regions: it is our earnest hope that an amicable sharing of necessary costs can be devised, which will ultimately benefit both our Regions and the Great Lakes Basin of which they are an important part.

RECOMMENDATIONS

This Report sets out a number of recommendations and provides back-up material in the form of technical reports.

The First Recommendation, set out in Section B, concerns the conduct and estimated costs of a sampling programme for the waters of Grindstone Creek.

The Second Recommendation, set out in Section C, concerns a programme of practical action on erosion control, involving the active co-operation of the Royal Botanical Gardens with the Halton Conservation Authority: it has been considered of sufficient urgency that action should soon be under way.

The Third and Fourth Recommendations, dealing with activities of the two Conservation Authorities in their respective areas of jurisdiction, are set out in Section D: these are concerned with the setting and maintenance of water quality standards, and with the carrying out of impact assessment for erosion control.

SECTION B

POLLUTANTS
IN

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Colin West
Hamilton-Wentworth
Regional Laboratories

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RECOMMENDATIONS ON WATER QUALITY

The Creek should be monitored at two or three points on the main stream from Waterdown Road to the mouth. The eastern tributaries should be checked immediately above their confluence with the main stream; two points would be adequate. Those tributaries flowing into Grindstone Creek near its mouth should be sampled as close to the main stream as feasible; this would add two more sampling points.

The samples from these points should be collected weekly throughout the summer, giving a total of approximately twelve collections. The water should be analyzed for B.O.D., total phosphorus, suspended solids and volatile suspended solids and total coliforms. Chlorophyll determination might also be included to indicate algal growth.

Above Waterdown Road the water should be sampled at fairly close intervals to locate the sources of sewage contamination. These particular studies should extend north of the village if early work indicates the need.

Samples taken above Waterdown Road should be tested for total and fecal coliforms; there is probably no point in chemical analyses. In these bacteriological studies it may not be necessary to sample a few set points weekly for the whole season. In fact it might be more informative to concentrate on one area for a few weeks and then move further upstream for a few more weeks.

The sampling and analyses recommended should determine within fairly narrow limits the sources of the major pollutants. When these sources have been found, effective measures may, in most cases, be taken to clean up Grindstone Creek.

In summary, the recommended survey involves the weekly

-2-

collection of 12 samples for twelve weeks. Seven of these samples are to be analysed for five parameters and the remaining five for two parameters, at an estimated cost of under \$3,000.

S.D.S. determinations - 7 samples per week \$ 35

Total S.D.S. " " " " " " 35

S.D. " " " " " " 35

Overall S.D. " " " " " " 35

Total Cold " " " " " " 35

S.D. C.G.S. could be substituted for S.D.S. to effect a 50% reduction in the above total.

Total Cold determinations - 5 samples per week \$ 25

Total Cold " " " " " " 25

Overall Cost of Laboratory Services \$100

Cost for the twelve week programme \$1,200

Sample Collection

Labour, four hours per week (estimated) \$ 20

Vehicle costs, 20 miles per week (estimated) \$ 10

\$.75 per mile \$ 15

Cost for the twelve week programme \$ 375

Overall cost of the programme \$1,575

Estimated details are as follows:

(1) Laboratory Services

					Cost per Week	Total Weekly Cost
B.O.D. determinations	-	7	samples	per week	\$ 35	
Total P	"	-	7	" " "	13	
S.S.	"	-	7	" " "	35	
Organic S.S.	"	-	7	" " "	17	
Total Coli	"	-	7	" " "	<u>49</u>	\$149

N.B. C.O.D. could be substituted for B.O.D. to effect a \$15 reduction in the above total.

Total Coli determinations	-	5	samples	per week	\$ 35	
Fecal Coli	"	-	5	" " "	<u>25</u>	\$ 60
Overall Cost of Laboratory Services						\$209
Cost for the twelve week programme						\$2,508

(2) Sample Collection

Labour, four hours per week (estimated)	\$ 24	
Vehicle costs, 28 miles per week (estimated) @ 25¢ per mile	<u>7</u>	\$ 31
Cost for the twelve week programme		<u>\$ 372</u>
OVERALL COST of the programme		<u><u>\$2,880</u></u>

POLLUTANTS IN GRINDSTONE CREEK

This report is based on data generated by the Ontario Ministry of the Environment over the ten year period 1965-74 inclusive. The data covers only two sampling points, one in the Village of Waterdown, about half a mile above the Sewage Plant and the other, near the mouth of the stream at Highway No. 2.

Because of the nature of human activities in the vicinity of Grindstone Creek it was felt that the major pollutants of concern were nutrients, bacterial contamination and silt, rather than industrial wastes. This study, therefore, concentrate on these factors.

It is necessary for the understanding of water pollution problems to comprehend the terms used and their significance, for this reason the following definitions are provided.

B.O.D. - Biochemical Oxygen Demand

Most bacteria, like other animals, consume oxygen in their life's activities. Their number, activity and oxygen demand is largely determined by the food available to them.

B.O.D. is a crude measure of the amount of available food which bacteria can consume in five days expressed in terms of the quantity of oxygen which they use in the process.

For Example: A container is completely filled with water having 15 p.p.m. dissolved oxygen (and some bacteria) and is sealed airtight and left for five days. After this period the oxygen content is found to have fallen to 5 p.p.m. therefore, the B.O.D. is 10 p.p.m.

Since bacteria do not always eat everything available in five days, their demand for oxygen can be twice as much or more if measured over a longer period. Bacteria have top priority on dissolved oxygen to the detriment of others who need it. Materials contributing to B.O.D. include starches, sugars, cellulose, fats,

proteins and virtually everything else of organic origin as well as such inorganic substances as ammonia.

Total Phosphorus - Tot. P.

Phosphorus in the form of phosphate is a valuable nutrient to plant life including algae. Since all phosphorus compounds, when present in water, eventually provide phosphate for plant growth it is more important to know the total phosphorus content rather than merely that which is immediately available.

Many authorities believe that algal growth in natural water is primarily dependent on the availability of phosphorus, i.e. that phosphorus is the limiting nutrient.

TKN - Total Kjeldahl Nitrogen

TKN is a measure of all the nitrogen present in its various compounds in water, excluding nitrate and nitrite. It includes nitrogen in the form of ammonia salts, and plant and animal protein. Nitrogen compounds are another important nutrient for plant growth, and at high concentrations are generally toxic to fish and the organisms on which they feed.

Algae

These are primitive forms of plant life frequently consisting of as little as one cell. Like other plants they require a suitable supply of nutrients and when subject to light they proliferate and grow exhaling oxygen in the process. Unfortunately, after death, they demand the return of all of that oxygen in the form of B.O.D. as they are decomposed to the elements from which they started. Because algae often live for months and then die and decompose in much shorter periods they can produce a very sudden and large B.O.D. in a water body.

Coli - Coliform Bacteria

These are the main bacterial indicators of polluted water. Their total absence indicates that the water is safe to drink, less than ten organisms per 100 ml.

Coli - Coliform Bacteria (continued)

indicates a level of pollution unlikely to be injurious to health. Water containing less than 2400 coliform bacteria per 100 ml. is considered safe for swimming.

S.S. - Suspended Solids

The dried weight of material which can be filtered from water. It consists of organic material and silt. Unfortunately the data for this report does not differentiate between these two types of material.

NUTRIENTS

The yearly average concentrations of various parameters have been plotted against the years of observation to produce the graphs appended to this report.

It is evident that there is a significant increase in nutrient concentrations between the upper and the lower sampling points. This trend is particularly marked with respect to phosphorus, the limiting nutrient, which more than doubles in concentration during most of the period studied.

The effect of the fertilizing of the waters shows very clearly in the dissolved oxygen concentration at the two sampling points. At the upper point dissolved oxygen levels are almost invariably below saturation point. In the placid waters at Highway No. 2 dissolved oxygen levels are frequently at supersaturation, a condition normally due to violent turbulence or vigorous photosynthetic activity (algal growth).

The I.J.C. for the Great Lakes stated in a 1969 report that Grindstone Creek contributed 4000 lbs. P per annum to Lake Ontario in 1966 and '67. The phosphorus graph shows that during these years the concentration of this nutrient was particularly low.

The author has calculated that the current contribution by the stream may be over 8000 lbs. P per year.

At present Waterdown Sewage Treatment Plant discharges 3000 lbs. P per year; so it appears that this is the source of three-eighths to three-quarters of the phosphorus at the mouth of the creek. The plant is expected to conform to the "less than one p.p.m. phosphorus" suggested by the Ministry of the Environment after improvements and enlargement. Unfortunately this performance is not mandatory for plants of less than one million gallons per day capacity; Waterdown's capacity is to be expanded from 200,000 g.p.d. to 400,000 g.p.d. If the plant conforms to the Ministry's guideline its annual phosphorus output, at the present operating volume, would be 700 lbs.

Levels of this particular nutrient upstream of the plant are not presently great enough to be of serious concern. It must be borne in mind, however, that phosphorus compounds are uncommon in our local geological structure so that most of that found in water originates in human activity, particularly agriculture. The expansion of such activities along the stream may be expected to lead to its deterioration and should therefore be closely monitored.

The TKN concentration increases noticeably as the creek flows from Waterdown to its mouth. Again the sewage treatment plant is probably the major source although data is not available to substantiate this. Hopefully improvements to the S.T.P. will reduce this to some degree by nitrification of ammonia during secondary treatment and subsequent reduction of nitrogen compounds to molecular nitrogen which is virtually inert.

B.O.D. in Grindstone Creek shows a large rise between the upper and lower sampling points. The I.J.C. report of 1969 stated that the stream contributed 55 tons of B.O.D. to Lake Ontario, calculations suggest a current value closer to 100 tons per year. Waterdown S.T.P. presently emits less than 6 tons per year and is, therefore, a minor source.

The origin of sufficient organic matter to require fifty to ninety odd tons of oxygen each year for its decomposition is at this point not known.

SUSPENDED SOLIDS

In 1966-67 Grindstone Creek discharged 2,260 tons of suspended solids from its mouth, of this, Waterdown S.T.P. may have contributed as much as three tons. These startling figures together with the murky appearance below Highway No. 2 suggest erosion. There are no analytical data available to confirm this opinion since organic and inorganic solids have not been differentiated. Whatever the nature of these solids, it does seem likely that considerable silting up is occurring in the broad slow moving stretch of the creek near its mouth.

It might be of interest at this point to compare Grindstone Creek with some other creeks in the area, for this purpose Table I has been prepared.

Information for it has been extracted from the I.J.C. report of 1969. In the table annual tonnages of the various parameters issuing from the mouth have been divided by the flow rate of the stream concerned. In looking down the column one can compare the relative concentrations of the different items in different streams.

TABLE I

TONS PER YEAR PER C.F.S. FLOW

CREEK	Flow(C.F.S.)	Tot. P	T.K.N.	B.O.D.	S. S.
Grindstone	26	0.077	1.46	2.11	86.92
Spencer	59	.102	0.47	1.89	42.25
Redhill	84	.286	2.61	6.62	10.29
Bronte	119	.034	0.79	0.61	18.48
Oakville	88	.125	3.18	2.72	38.97
Credit R.	280	.171	2.14	2.96	38.21
20 Mile	80	.287	3.89	2.75	64.87
40 Mile	17	.941	3.18	10.52	32.47

Table I shows quite clearly that Grindstone Creek is better than most except with respect to suspended solids. This is not necessarily flattering since most streams in Southern Ontario are quite heavily polluted, even the relatively very clean Bronte Creek.

COLIFORM BACTERIA

For this portion of the report a little more data is available in the form of bacterial studies conducted in 1971 at various points above the S.T.P.

No graphs have been prepared of coli counts because they oscillate sharply making graphic interpretation very difficult. For the same reason no detailed analysis of actual numbers have been provided.

At Highway No. 2 coliform counts range generally from hundreds to hundreds of thousands of organisms per 100 ml. Occasionally even higher counts are observed but numbers of a few thousand are most common. The Creek at this point is, most of the time, unfit for bathing although a brief accidental immersion would probably not be harmful.

At Waterdown Road coli counts are mostly in the range of thousands to around one million per 100 ml., noticeably worse than at the mouth of the stream.

The 1971 studies reveal coli counts into the tens of millions at various points between 4th Concession Road and the S.T.P. This indicates heavy sewage pollution either from faulty septic systems or deliberate discharge of sanitary wastes into the stream. Effluent from the sewage plant is chlorinated before discharge and coliform counts therein are low, generally ranging from units to hundreds of organisms per 100 ml. Since most counts are in the tens this water is almost potable from a bacteriological stand point, certainly it is fit for swimming and is a great deal better than the receiving streams.

CONCLUSIONS

In view of the limited data available for the report, any conclusions are tentative and may be subject to radical revision as more information becomes available.

It appears that suspended solids, B.O.D. and bacterial contamination may be the major problems. Improvements to Waterdown S.T.P. may reduce the TKN level and should definitely lower the phosphorus concentration in the Creek but will have little effect on B.O.D. The information at hand shows that the S.T.P. cannot be responsible for more than about one tenth of the B.O.D. at the mouth of the Creek. The levels recorded must be due to organic matter being introduced to the stream below Waterdown or to profuse algal growth. Because high B.O.D. has been found at Highway No. 2 during winter months when algae are sparse the former possibility is more likely.

If B.O.D. and suspended solids can be controlled, the mouth of Grindstone Creek could provide good sport fishing. Even in its present condition it draws numbers of mostly youthful anglers who enjoy some success with coarse fish.

If bacterial pollution can be brought under control, health hazards to youngsters playing in the stream at such places as Hidden Valley Park would be reduced.

In general, it seems it may be possible to upgrade Grindstone Creek to a position of greater recreational and aesthetic value than at present.

B.O.D. IN GRINDSTONE CREEK (p.p.m. vs. year)

At Waterdown
At Highway #2

6

5

4

3

2

1

65

66

67

68

69

70

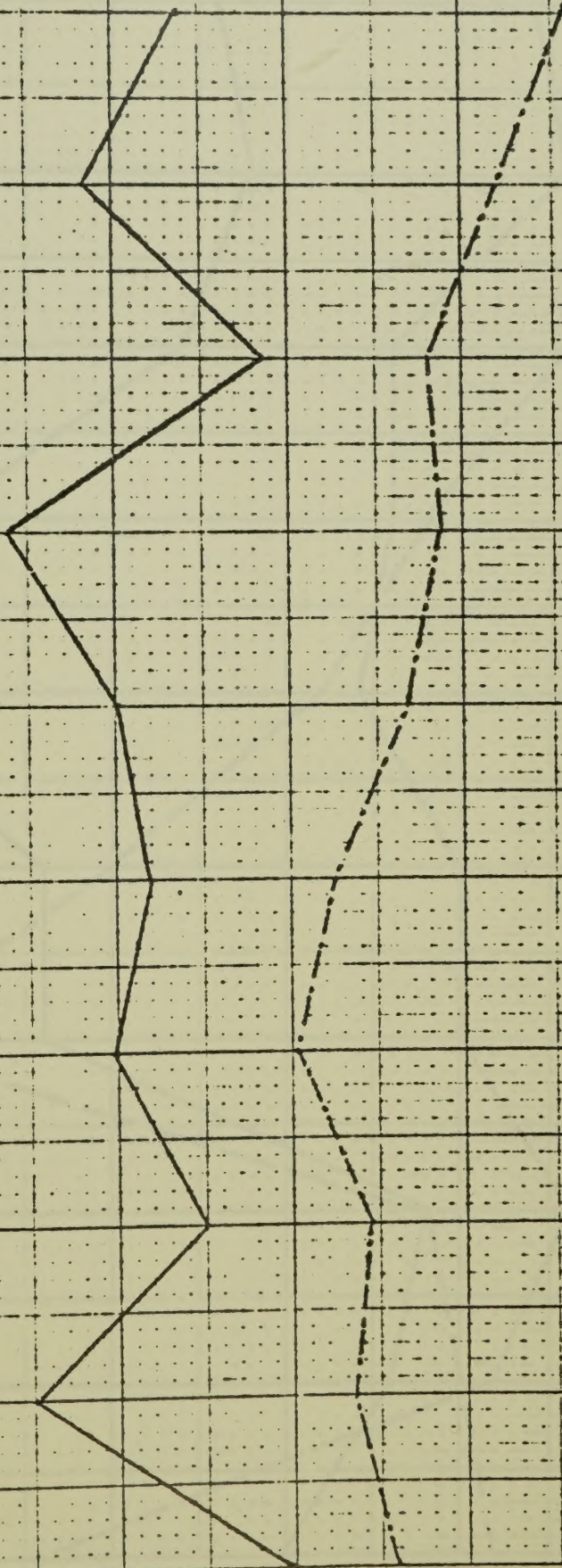
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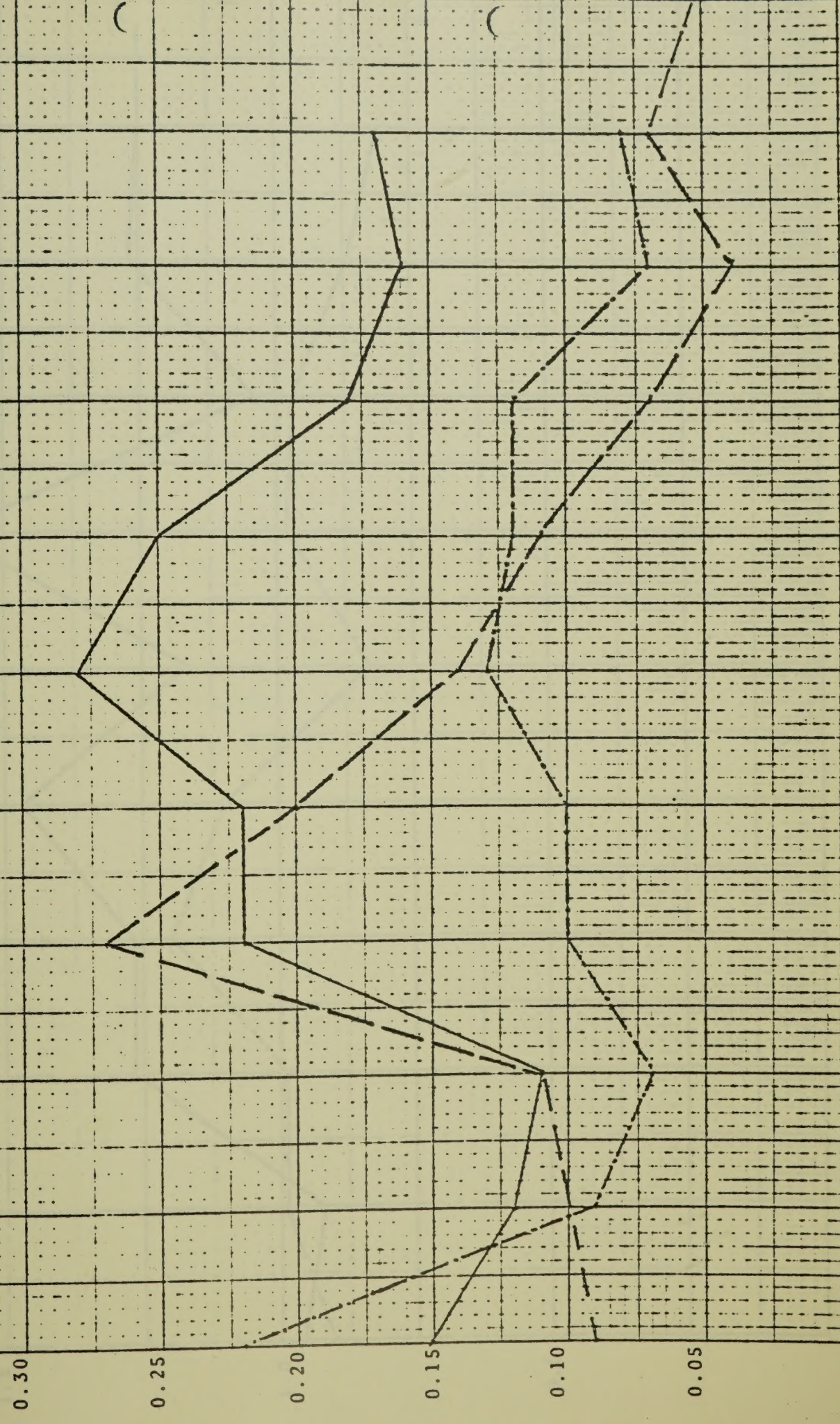
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B1



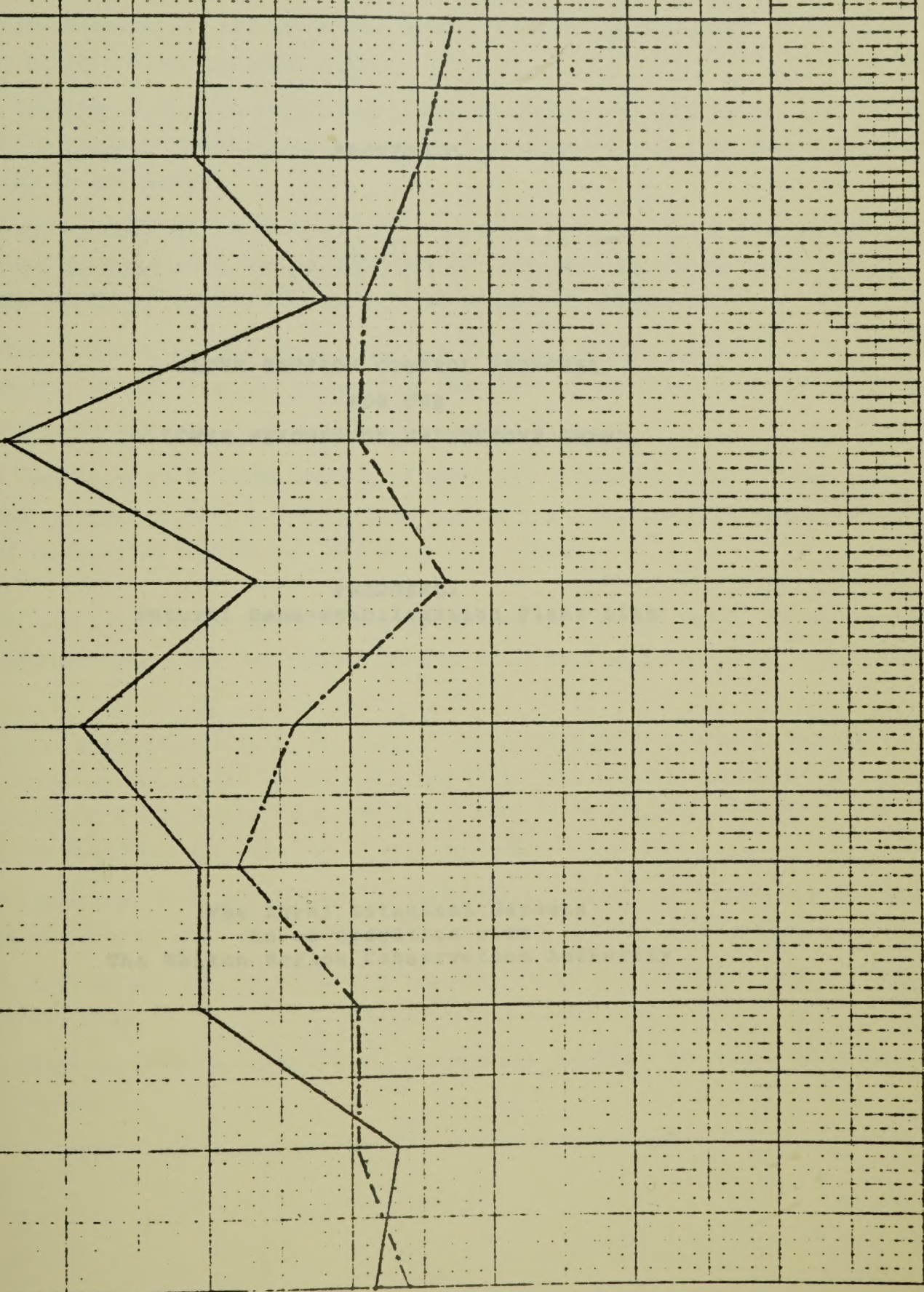
TOTAL PHOSPHORUS IN GRINDSTONE CREEK (p.p.m. vs. year)

- At Waterdown Road
- At Highway #2
- At Bay Stn #1



TKN In Grindstone Creek (p.p.m. vs. year)

At Waterdown
At Highway #2



65 66 67 68 69 70 71 72 73 74

As a result of a proposal of the Grindstone Creek Committee, the Royal Botanical Gardens, in co-operation with the Halton Region Conservation Authority, plans to embark on a slope erosion control project.

The location chosen has been of considerable concern for some years, and lies on the westerly slope of the Grindstone Creek valley between Plains Road West and Grand View Avenue in Burlington.

SECTION C

The main purpose of the project is to restore a degraded erosion-prone area, selected and demonstrated by the committee to be vulnerable to erosion in the valley of the Grindstone Creek, or to improve the revegetation of degraded slopes.

A plant list is recommended for use in slope restoration and which is available from the Royal Botanical Gardens.

**SLOPE EROSION CONTROL PROPOSAL
FOR THE
LOWER REACHES OF GRINDSTONE CREEK**

The most westerly is under the Plains Road West Grindstone Creek bridge, where the bridge contractors left a considerable area of raw slope which was improved by Alderbrook Landscaping in 1973 but bare slope still shows.

**PROPOSAL:
Natural Bank-Stabilization Plant List**

Next, and east, is a large area of raw slope which was improved by Alderbrook Landscaping in 1974. The area is now covered by a large concrete wall and a large concrete wall is visible in 1974.

Lastly is a landfill site at the rear of the Inglewood Hotel and Cargo Transport in a ravine which was closed in 1975. The landfill is now brick and rubble covered and the ownership of the filled area is in dispute. The first area is in public ownership the rest two in private hands.

**The Royal Botanical Gardens
in co-operation with
The Halton Region Conservation Authority**

The first target area is visible to the public from the Old Snake Road and the Spring Garden area.

The other two areas are not readily visible and therefore of little value for a public exhibit.

It is suggested that the area near the bridge be designated as the interpretive area.

As a result of a proposal of the Grindstone Creek Committee, the Royal Botanical Gardens, in co-operation with the Halton Region Conservation Authority, plans to embark on a slope erosion control project.

The location chosen has been of considerable concern for some years, and lies on the easterly slope of the Grindstone Creek valley between Plains Road West and Grand View Avenue in Burlington.

The main purpose of the project is to improve a serious erosion problem presently existing and to demonstrate the possibilities to landowners in the valley of the Grindstone Creek, of inexpensive revegetation of denuded slopes.

A plant list is included which comprises the major plants recommended for use in slope restoration and which was prepared by the staff of the Royal Botanical Gardens.

The site is composed of three separate problem areas.

The most westerly is under the Plains Road West Grindstone Creek bridge; here the bridge contractors left a considerable area of raw slope which was improved by Aldershot Landscaping in 1975 but bare slope still shows.

Next, and easterly is landfill site on the property of one Varga, the sand and broken concrete covers massive organic remains of a large warehouse fire in Hamilton in 1974.

Lastly is a landfill site at the rear of the Esquire Motel and Cargo Transport in a ravine which was deeded to the R.B.G. in 1975. The landfill is now brick and rubble covered and the ownership of the filled area is in dispute. The first area is in public ownership the last two in private hands.

The suggestion is to get the various landowners involved to cooperate with the Committee on reducing erosion and making the remedies visible to the public.

The first target area is visible to the public from the Old Snake Road and the Spring Garden area.

The other two areas are not readily visible and therefore of little value for a public exhibit.

It is suggested that the site near the bridge be designated as the interpretive site.

List of natural bank-stabilization plants

Common Name	Scientific name	Preferred Exposure	Mature Height
Aspen Trembling	<i>Populus tremuloides</i>	EWS	60
Barberry	<i>Berberis thunbergii</i>	+	3
Bittersweet nightshade	<i>Solanum dulcamara</i>	+	Vine
Blackberry	<i>Rubus allegheniensis</i>	N	5
Choke cherry	<i>Prunus virginiana</i>	+	35
Clematis	<i>Clematis virginiana</i>	EWN	Vine
Cottonwood	<i>Populus deltoides</i>	EWS	70
Currant	<i>Ribes americana</i>	EWS	2
Cocks	<i>Rumex sp.</i>	+	2
Elderberry	<i>Sambucus canadensis</i>	EWS	12
Fireweed	<i>Epilobium angustifolium</i>	EWS	3
Field mustard	<i>Hesperis & Brassica rapa</i>	+	2
Grape	<i>Vitis aestivalis</i>	+	Vine
Gray Dogwood	<i>Cornus foemina</i>	+	6
Hazel	<i>Corylus spp</i>	S	25
Horsetail	<i>Polygonum aviculare</i>	+	2
Manitoba maple	<i>Acer negundo</i>	+	55
Norfolk Island	<i>Philadelphus coronarius</i>	EWS	6
White mulberry	<i>Morus alba</i>	EWS	19
Paper birch	<i>Betula papyrifera</i>	N	45
Slender leaved willow	<i>Salix amygdaloides</i>	+	25
Periwinkle	<i>Vinca minor</i>	+	1
Poison Ivy	<i>Toxicodendron radicans</i>	+	Vine
Red-barked ash	<i>Xanthoxylum americanum</i>	S	10
Primrose - Evening	<i>Oenothera biennis</i>	S	3
Raspberry	<i>Rubus idaeus</i>	+	4
Sumac	<i>Rhus typhina</i>	+	20
Teasel	<i>Dipsacus sylvestris</i>	+	5
Touch-me-not	<i>Impatiens capensis</i>	+	4
Virginia Creeper	<i>Parthenocissus inserta</i>	+	Vine

Legend: E-East
N-North
S-South
W-West

+Tolerant to location

SECTION D

A REPORT ON SILTATION PROBLEMS IN
THE GRINDSTONE CREEK
AND
WEST HAMILTON HARBOUR

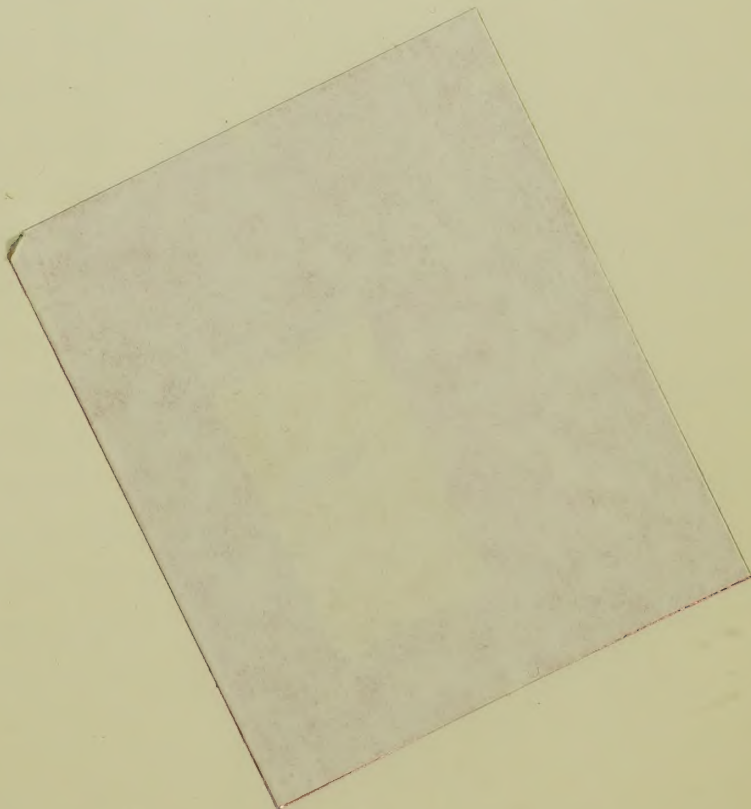
BY

Paul Attack, M.C.I.P. (Prov.)
Environmental Planner
Halton Region Conservation Authority

George McKibbin, Assoc. A.I.P.
Planner
Hamilton Region Conservation Authority

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INTRODUCTION

The Grindstone Creek Marsh and environs contain remnant plant and animal populations which at one time were widely distributed throughout Cootes Paradise and the south shore of Hamilton Harbour. This area may represent the last existing situation for several species of aquatic and emergent plants along the entire Halton-Wentworth Waterfront.

The purpose of this report is to examine the siltation and water quality status of Grindstone Creek Marsh and identify sources of the deterioration of the Creek and of the rest of the west end of the Harbour. Remedial measures are proposed aimed at easing the pressures to this important habitat area.

RECOMMENDATIONS

1. Acceptable water quality standards appropriate to Grindstone Marsh and hence to upstream and land use practices are being presented by the Royal Botanical Gardens.* They should be adopted and enforced in order to maintain and enhance the Marsh.
2. The impact of bridging and culverting the Creek and its tributaries particularly in the vicinity of the Marsh should be examined with a view to predicting future trends and to assist in the evaluation of future plans. Erosion and sedimentation processes and their relationship to bridges and culverts in the vicinity of the Marsh should be studied in an Impact Assessment of the lower Grindstone Creek Watershed. The Halton Region Conservation Authority should include this study as part of the sensitive areas mapping programme proposed for 1977.
3. In connection with erosion control, existing regulations should continue to be enforced and the municipal authorities concerned should be advised to endorse such regulations in Official Plans and related documents.
4. To improve the stability of slopes where erosion problems have been observed, it is recommended that a demonstration project be established jointly between the Royal Botanical Gardens and the Halton Region Conservation Authority, to show vegetative slope stabilization in an area in the lower reaches of the Creek. It is also recommended that the Conservation Authority establish contact with landowners in the area, to arrange for advice or assistance as needed, and that a brochure on vegetative erosion control possibilities be prepared in conjunction with the Royal Botanical Gardens.

*See Appendix

LANDSCAPE OF THE GRINDSTONE WATERSHED

Above the escarpment, the landscape is relatively flat and rarely exceeds a 10% slope. Headwater areas and valley floors are flat while the bordering moraines are slightly undulating. Below the escarpment, the terrain is considerably more rugged with several deeply etched ravines.

During glaciation, the area was covered several times by ice shields. The retreat of the last glacier occurred roughly 12,000 years ago. This retreat was staged resulting in the formation of moraines interspersed with glacial spillways above the escarpment. Large sections of the Grindstone Creek flow parallel to the escarpment following what was a glacial spillway or lake bed. Lacustrine deposits are found in these spillways indicating that some ponding may have occurred during the glacial period. To the west and north, there exists an extensive limestone bedrock plain. This plain is fractured with the result that the surface drainage pattern is nonexistent. Rather, the bulk of the water falling on the plain percolates into the bedrock and flows out towards the Grindstone Basin creating extensive areas of poorly drained soils where the water table re-emerges or discharges into the surface drainage system.

The relationship between surface and ground water flows is extremely close throughout the bulk of the watershed. As one moves downstream, each moraine deposit acts as a barrier resulting in lateral stream flow in relation to the escarpment. Poorly drained soils associated with a high water table are found in the upstream tributary areas. In addition, poorly drained soils on the downslope side of each moraine indicates that waters percolating into each moraine are being partially released.

Below the escarpment, several parallel streams are found running through deeply etched ravines. Base flow for these streams comes from ground water percolating out of bedrock seams in the face of the Niagara Escarpment. These streams flow through valleys cut into the shale bedrock underlining the limestone layers of the escarpment. Very little moisture or run-off is absorbed by the shale rocks and residual soils as internal drainage is very slow.

The bulk of the soils contained within the watershed above the escarpment can be divided into two classes on the basis of their parent material. Halton Till is found on the moraine deposits within the area. Soils derived on the moraines are basically varied in texture, with the bulk of same being clay based. Percolation rates are slow although due to slope, these soils are fairly well drained. The ground water table can be found at the surface during the wetter seasons. This level retreats rapidly downwards during the drier seasons.

Outwash sands and lacustrine deposits comprise the second major category. These soils are coarser and have the capability of being well drained internally due to high percolation rates. However, discharge from bedrock aquifers from local limestone outcrops to the north and north west and the dam effect caused by moraines block the free movement

Landscape of the Grindstone Watershed continued...

of ground water. Wetland areas are found within these deposits due to the high water table. Local erosion from adjacent moraines and decomposition of indigenous wetlands vegetation has added, over time, a high organic and clay silt content to the surface of these deposits. The presence of these autogenic forces in which fresh water wetland areas become filled with decayed vegetative debris has established the possible presence of interesting natural habitats. Two of these areas are presently under study in the Biological Sensitive Area Work presently being conducted under the auspices of local Conservation Authorities for the Regional Municipality of Hamilton-Wentworth.

Below the escarpment, tributary branches of the Grindstone Creek pass through deeply etched ravines cut into shale bedrock. Residual soils formed on the shale rock are thin, forming 3 to 8 feet in flat areas. Internal drainage is extremely slow.

In thickly bedded clay shale regional landslides are not common, and the major forms of mass wasting are soil creep and slumps. Slumps can be expected if the natural slopes are steepened by erosion or construction. If this shale is inter-bedded with other more permeable materials, the possibility of landslides will be more common. It would appear that the ravines below the escarpment are extremely susceptible to erosion. Where slopes have been cleared, surface erosion can readily expose bedrock making the revegetation of these slopes extremely difficult.

FIELD SURVEY

A one day field survey to ascertain major siltation source areas and causes was conducted by car on March 26, 1976. The entire Grindstone Creek watershed was covered but time restrictions dictated that only previously identified erosion problems and those visible from the road could be included. Notwithstanding these restrictions, a fairly representative picture of that situation was obtained.

The main factors influencing the degree of erosion expected are:

- (a) Soil Characteristics - While silt and fine sand are the most erodable due to their particle size, clay erodes severely when there is a high runoff velocity in combination with the impervious nature of clay.
- (b) Vegetation - Good vegetative cover reduces runoff velocity; increases soil porosity; holds soil in place; and filters out sediment.
- (c) Topography - Slope length and gradient have a direct relationship with the extent of erosion.

The following sources of sediment in the creek were noted:

- 1. sheet erosion - a thin erosion effect over a widespread area such as a sloping farmers field
- 2. rill erosion - very small but numerous gullies on slopes such as road cuts and embankments
- 3. gully erosion - deeply cut V-shaped gullies such as those in the Burlington "Badlands" area
- 4. channel erosion - bank erosion from the force of water at the bends in streams and vertical cutting into the stream bed
- 5. fill problems - fill areas on stream banks that are unstabilized
- 6. development - urban type development where extensive regrading had exposed the bare soil for a period of time
- 7. road cuts - embankments and hill cuts on a road where the slopes were unstable and eroding
- 8. excavations - sand pits, brick works and quarries

The findings were divided into two areas, above the escarpment and below the escarpment.

In the area of the Grindstone Creek watershed above the escarpment the stream tributaries are slow moving due to the relatively flat topography. Along a large portion of the stream the channel has been

Field Survey continued...

straightened and deepened to accommodate agricultural pursuits. Since these ditches are not stabilized with vegetation in most areas, channel erosion is fairly extensive.

Several stream tributaries were channeled under the Land Drainage Act around 1910 to 1930 and several of these channels have silted in, thereby becoming ineffective. Channelization in the groundwater discharge wetland areas has created an erosion problem, since the organic soils are no longer stable.

There is evidence of sheet erosion from farmlands in the area particularly on the tops of undulating hills.

From the water quality data provided by the Hamilton-Wentworth Regional Lab it appears that a great deal of the suspended solids in the water silt out before reaching Waterdown. This can be attributed to the flatness of the topography above the escarpment.

The extraction of peat from swampy organic areas is practised in the upper reaches of the watershed and certainly appears to be a source of sedimentation in the stream.

Many low areas are susceptible to spring flooding and are also used for market gardening. These fields would erode while flooding could also be a major source of chemical pollution.

Several fill problems and stream alteration situations were identified and are being investigated under the Conservation Authority's fill and flood plain regulations.

The major source of siltation in the entire watershed was in the area below the Niagara Escarpment. In this region, steep slopes in combination with relatively impervious clay and shale cause any exposed soil to erode rapidly.

The main siltation sources identified in the survey were as follows:

- (a) Road cuts and embankments which are quite steep, numerous and often lacking in any form of erosion protection.
- (b) Extensive channel erosion as the many tributaries meander through deep valleys and cut vertically through the shale bedrock.
- (c) Several fill problems over steep wooded valleys leaving unstabilized and eroding banks. Many of these problems have existed for many years.
- (d) Development of industrial and residential lots and the creation of new roads and highways has left areas of exposed clay. Some areas are exposed only for a short time while others are left for years.
- (e) Excavation and regrading operations associated with pits, quarries and industrial developments.

Field Survey continued....

- (f) The slope of the Grindstone Creek valley is so steep that in many areas, there is natural sheet erosion throughout the area where extensive ground cover had not taken hold.

ANALYSIS

(a) Erosion

The erosion characteristics of the Grindstone Creek can be divided into two classes: Those prevalent below the escarpment, and those existing above the escarpment.

Below the escarpment, an unusually sensitive situation exists with respect to erosion trends. Stream stabilization (towards which all streams tend) involves lateral movement and modification of the stream gradient through a process of erosion until some steady state is achieved. Lateral movement and the creation of a steady gradient are related, so that to modify the gradient would result in an increased lateral movement while a modification of the lateral movement results in an increased rate of erosion to bring the gradient into balance. The effect of development of residential areas, bridge crossings, etc. within the valley floor is to restrict the free lateral movement of the stream. Eliminating the possibility of that action at any point along the stream, especially on nearly flat land where it tends to exhibit the greatest amount of lateral movement, results in the instability of the entire stream system from one end to the other. Stream action is then directed to re-establish a steady state by changing its gradient accompanied with an intensive new stage of erosion both upstream and downstream.

With increased erosion upstream come increased rates of deposition downstream. This would suggest that even the slightest alteration of the stream below the escarpment such as that caused by the 403 Highway, can be expected to produce dramatic effects downstream.

Above the escarpment, the same effect mentioned previously is found along those drainage channels constructed to drain wetlands created by a high water table. Not only has this practise been ineffective, but it has also induced erosion. In addition, siltation and erosion rates throughout the area are related directly to the removal of vegetation along the creek and tributary streams. This buffer along the creek has been removed over time, for the purpose of cultivation, grazing and rural development. Silt loads and erosion rates are directly related to these agricultural practices adjacent to the stream. Silt loads are most substantial during periods of peak flow.

Finally, erosion rates throughout the watershed are directly related to the alteration of drainage characteristics as the transition between a natural to urbanized watershed occurs. The addition of non-porous surfaces as well as the removal of vegetation on a large scale has resulted in massive increase in peak flows. This will accentuate erosion and siltation trends in the future.

EROSION CONTROL MEASURES

The list below describes the basic principles involved in erosion control.

1. Keep all disturbed areas as small as possible.
2. Stabilize all disturbed areas immediately.
3. Minimize storm runoff velocities.
4. Retain sediment at the source.

The following methods have been utilized to protect slopes. They vary in applicability and fiscal feasibility.

1. diversion channels to prevent water from running down a slope or to prevent runoff from reaching a stream directly.
2. slope drains to contain runoff and conduct same to the bottom by mechanical means.
3. retaining walls to stabilize slopes.
4. seeding, sodding or planting to revegetate slopes.

The following methods are practical in protecting streams from erosion and its effects.

1. planting buffer strips to filter sediment before it reaches a watercourse.
2. install rip rap (small boulders) to protect banks.
3. build check dams and weirs to reduce stream velocity..
4. construct sediment traps to capture silt before it enters a natural watercourse.

General procedures for controlling surface drainage include:

1. the planting of grasses waterways in farmers fields
2. the construction of concrete or rip rap drainageways on steep gradients
3. sediment filters around storm drain inlets
4. sediment traps and rip rap protection around storm drain outlets
5. maintaining stabilized slopes and sediment traps for borrow pits

SECTION E

APPENDIX

Acceptable Water Quality Standards
For Fish, Aquatic and Wildlife in
Grindstone Marsh and Bay

:Royal Botanical Gardens

Fish Observed in Grindstone Creek
1965 - 1975

:Royal Botanical Gardens

Survey of Amphibians and Reptiles
in Hendrie Valley (part of Grind-
stone Creek) and Cootes Paradise
during June, July, August 1975

:Royal Botanical Gardens

Mammals Observed and Assumed

:Colin West

Bird Check-List

:George North
Alan Wormington

Floods as Man-Made Disasters

:Maurice Arnold

Table 3.1.9 from 1969 Report to International Joint Commission

Bibliography

FROM THE ROYAL BOTANICAL GARDENS

Acceptable water quality standards for Grindstone Marsh and Bay for fish, aquatic life and wildlife:

pH: 6.5 - 8.5

B.O.D.: Less than 5 mg/liter

Dissolved oxygen: North less than 5 mg/liter

Solids: Less than 5 mg/liter

Turbidity: Less than 25 Jackson units

Phosphorous: Less than 0.5 mg/liter

Chlorophyll (May to October): Less than 50 mg/liter

Ammonia (flow through bio-assay with cageo fish):

Levels not higher than large-mouth bass or pike can tolerate.

FISH OBSERVED IN GRINDSTONE CREEK 1965-75

Bowfin	Bluegill
Mooneye	Sea lamprey
Shad	Ale wife
Carp	Smelt
Common white sucker	Chub
Goldfish	Northern pike
Brown bullhead	Various minnows
Small mouth bass	Gar
Chinook salmon	Sunfish
Perch	

A SURVEY OF AMPHIBIANS AND REPTILES IN
COOTES PARADISE AND HENDRIE VALLEY
MADE IN JUNE, JULY, AND AUGUST 1975

FROGS - Green Frogs (*Rana clamitans melanota*) were found to be plentiful with Leopard Frogs (*Rana pipiens pipiens*) in somewhat smaller numbers. Bullfrogs (*Rana catesbeiana*) have been wiped out by pollution and/or fishing and none were found in the survey. They have been re-introduced into Cootes Paradise and have recently been heard for the first time in years.

TURTLES - Painted Turtles (*Chrysemys picta marginata*) were quite plentiful with a smaller number of Snapping Turtles (*Chelydra serpentina*) and some Map Turtles (*Graptemys geographica*). Musk and Soft-shelled Turtles were found in small numbers in one pond near the Valley Inn.

TOADS - The American Toad (*Bufo americanus*) was noted in large numbers throughout the area (one per step in some places).

SNAKES - Abundant quantities of Garter Snakes (*Thamnophis sirtalis sirtalis*) were observed with Northern Watersnakes (*Natrix sipedon sipedon*) not so common. The Redbacked Salamander, once common, would seem to have become quite rare as only a few were found.

MAMMALS OF LOWER GRINDSTONE CREEK AND VICINITY

Chipmunk	0
Cottontail Rabbit	0
Coyote (Brush Wolf)	
Fieldmouse	0
Grey Squirrel	0
Ground Hog (Woodchuck)	
Muskrat	0
Raccoon	
Red Fox	0
Skunk	0
Whitetailed Deer	0

0 Indicates that members of the species have actually been observed.

The remainder are probably present with the exception of the Coyote. The latter is known to be widespread in Halton and Wentworth Counties and may possibly be found near Grindstone Creek.

Hamilton Naturalists' Club

CHECK-LIST OF THE BIRDS OF THE HAMILTON AREA

(1975)

Comprising 331 species, 1169 forms that have occurred within a 75 mile radius of Northern Castle, Hamilton, Ontario. Seven forms are marked by the "A C U" character considered to be subspecies, colour morphs or hybrids by the A C U Character. Specimens of birds in small game traps or accidentally should be referred to the Hamilton Bird Records Committee using the appropriate report form.

Floods as Man-made Disasters

by Maurice Arnold *

The periodic onrushes of streams and ocean waves frequently bring economic disaster and human trauma. We call such occurrences 'natural disasters', articulating a human penchant for dealing with effects rather than causes. But in the main the real cause of damage is faulty land management and unwise governmental programmes, which in turn usually result from a failure of decision-makers to understand or apply rational planning precepts about riverine and estuarine systems. Undue reliance on structures to control the water's great energy is the product of that failure, and the reliance in turn tends to produce further disasters and tragedy.

This paper will present reasons why the structural approach to flood control seems not to have been effective, and why other nations should follow the lead of the more enlightened ones which guide land use in flood-plains and co-ordinate relief programmes in such a manner that they do not increase the risk of floods.

The flood plain is the land area which, lying near to a water body, absorbs the excess energy of higher water caused by unusual run-off and/or tides. The one-hundred-year flood plain — that area which has a one per cent or greater chance of being flooded — in the United States is estimated by the U.S. Task Force on Federal Flood Control Policy (1966)* to occupy about 5 per cent of a nation's total land surface. The proportion in other nations varies substantially and statistics are not available for all nations, but from one to twenty per cent seems a reasonable estimate for this discussion. Lands that are subject to a significant flood risk are thought to occupy about 7 per cent of total lands in the United States (White *et al.*, 1975).

Probably, the humans living on flood-plains have decreased in numbers over the years — until recently. Historically, Man located his cities on flood-risk lands, for when he had no real choice; he was drawn to the water's edge for economic and technological reasons. As these reasons became less compelling, when floods came, humans probably tended to move from the high-risk lands, while others, when migrating, moved to high ground. When came improvements in our

ability to control floods by structural means. Populations-at-risk, and others, were encouraged to stay or return to the flood-plain — unless strict land controls had been instituted downstream. Thus, those countries which relied on structural means to combat floods apparently underwent an increase in flood-risk populations, and this was associated with an increase in damage potentials.

In the United States, for example, the size of the population that is subject to flooding appears to have increased since 1937 (the year in which the Government adopted a structurally oriented national flood-control programme). Despite expenditures well in excess of 12 thousand million dollars since then, the population seems to be more endangered than ever. Countries with little or nothing in the way of flood-control programmes, while sometimes suffering disasters of headline proportions, do not seem to have had as much of an increase in relative populations-at-risk as the United States. Nations and locales which rely more on land management than on flood control, do not seem to have experienced an upswing in danger. Clearly there is a need for correlation between the extent of the risk and the selection of

flood-control devices. Specifically, the choice of structural means without proper land management as a corollary may cause damage and losses.

Effects of Principal Flood-Control devices

The means which we use, singly and in combinations, to control or contain excessive water-energy, are the dam, the channel, the levee, the sea-wall, and flood-plain management. The dam is a favoured device for controlling run-off by nations that do not use land-management techniques (Fig. 1). Its reservoir is effective for a period — maybe 50 to 100 years — depending on the level of flooding which it is designed for, on the sedimentation capacity, and on the other uses that are made of this artificial lake. Its ability to control floods diminishes progressively, and eventually the reservoir will fail as a flood control device unless Herculean efforts are made to dredge and bulldoze sediment from its bottom and upper reaches.

While the dam is favoured, the channel is more frequently used by structure-oriented officials. The channel — also called a canal or lateral — is simple, as the stream is ditched, straightened, and generally concreted (Figs. 2, 3 and 4). Obviously, its protection is limited to the area where the channel is located; it increases the need for protection downstream, as it adds to water velocity or quantity below. Rather than being called a flood-control mechanism, the channel is more properly termed a 'flood-threat-transfer-device'. Its life is determined by design and construction methods, by the amount of maintenance it receives, and by the nature of manipulation upstream. As can be inferred from Fig. 4, its maintenance is apt to be very costly.

The levee — a lineal dam — is popular in lowlands. Its effect on flooding is like that of the channel, and the degree of effect varies with the width of the levees in relation to the stream and flood-plain. Its life is dependent mainly upon design, location, maintenance, and upstream activities.

Sea-walls and groynes (also called jetties) are used to reduce wave action by absorbing and redirecting the energy of the sea (Fig. 5). Both are referred to here as 'sea-walls', as their purpose is similar when used for flood control. Generally, sea-walls directly confront waves, while

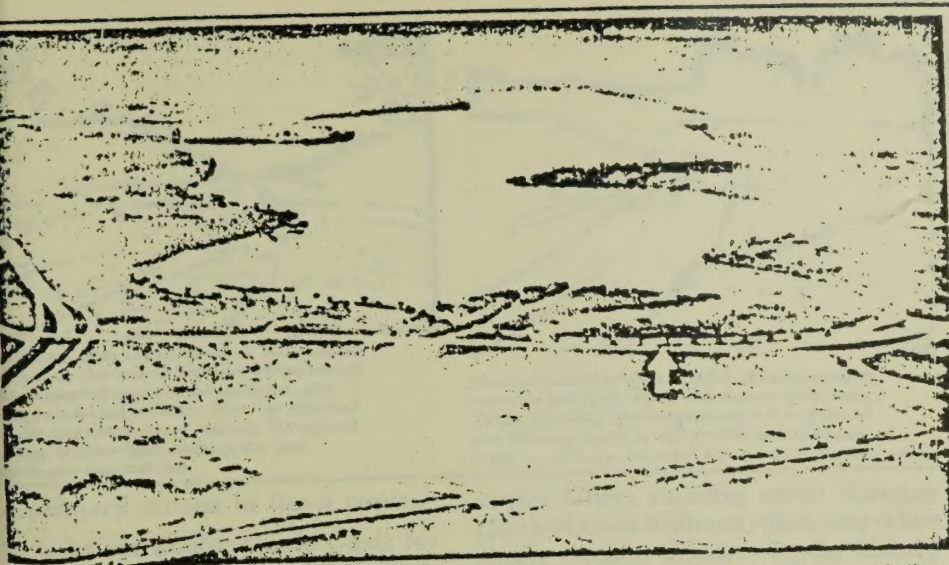


Fig. 1. White Rock Lake late in 1967. The broken white line pointed to by the arrow in the foreground indicates the old shoreline of headwater of stream entering from left where sedimentary filling has surfaced extensively. Large cars on the highway in the foreground indicate scale.

groynes may cut across the main current or lie parallel or obliquely to its flow. Their effectiveness as flood-control devices depends for the most part on their design, maintenance, sediment charges, and severity of wave action.

Flood-plain management is becoming more and more used in the United States and many other countries. It is basically a land-management tool, and the term refers to a regimen in which the flood-plain is kept essentially free from structures. It generally does not alter flooding patterns, as its purpose is to preserve natural means of flood control. It is the only method which is effective in the long run, for if it is planned adequately, its life is not as dependent on maintenance and upstream activity as are the structural alternatives. The effectiveness of these tools depends upon how they are deployed in a flood-control system.

Weakness of the Structural Strategy

Logic and evidence, although incomplete, seem to argue against deploying only structures; there now seems good reason to think that structures should rarely be employed for flood control. The case against relying solely on a structural strategy to abate floods rests on the following four main arguments: it is insufficiently effective in the long term and is often counter-productive in that it encourages human occupation of the flood-plain; it causes severe and unnecessary losses of resources; it discourages the economic use of land; and it is not cost-effective.

The effectiveness of structures when used alone has been a source of controversy in the United States

for over a century. In the last two decades, however, the advocates of dams, channels, levees, and sea-walls, have modified their views perceptibly. The evidence against structures has mounted as the structures have aged and more information about them has become available. Morgan (1971) alleges that the great flood of 1927 in the lower Mississippi was due in large measure to levees and not to unduly large run-off. Belt (1973) points out that the damaging flood at St. Louis in 1973 contained less water than a

previous flood which had done less damage — despite construction meanwhile of an upstream system of dams and channels on the Missouri and Mississippi Rivers. These critics are now being joined by many others.

Yet, it is undeniable that structures do give short-term local relief, and this is perhaps why they constitute a significantly vulnerable point. For protection encourages increased occupation of the flood-plain, introducing the elements of future disaster that may be more serious than if nothing had been done. The local relief sets in motion a vicious cycle of flood losses, flood protection, further flood-plain occupancy, further losses, further protection etc. Commitment to structural solutions can only mean further commitment. The cycle is demonstrated in Denver, Colorado, a city which has several dams (in-place and under construction) and channels for flood protection. Yet these structures have made Denver more susceptible to flood damage than ever before. Observers of the Denver scene conclude that construction of flood-protection works has hastened the development of the flood plains, and thus structures begat development which begat more structures. Denver's flooding prospect is repeated many, many times throughout the earth where structures are

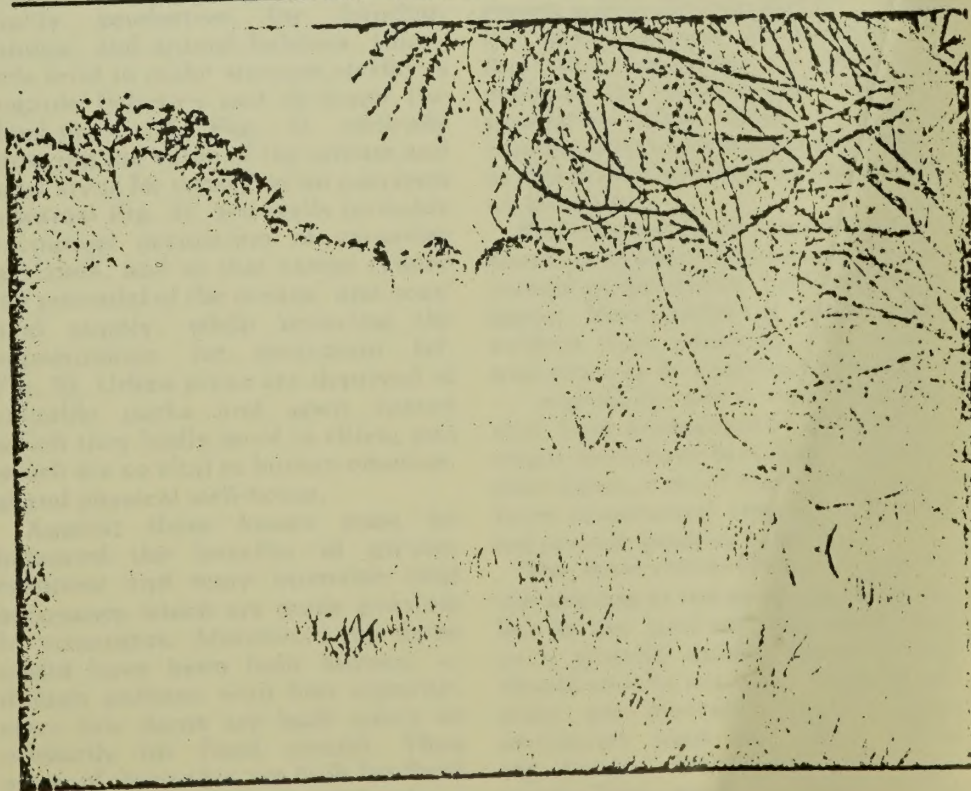
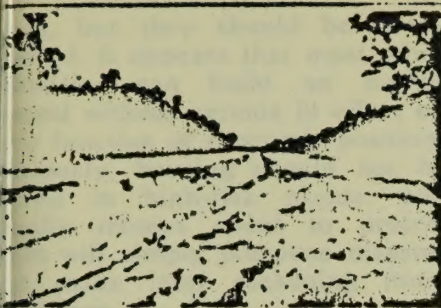
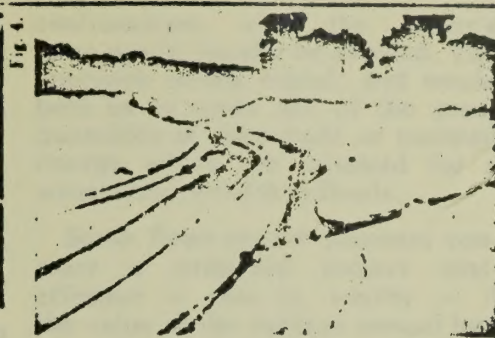


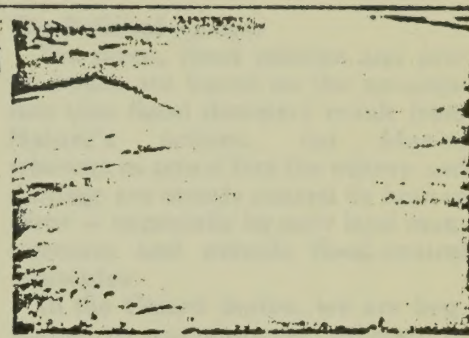
Fig. 2. Shoal Creek, Illinois, before channelization. The natural stream is of varying width, with wide stretches containing run-off and creating fertile conditions for biological diversity and concomitant natural beauty.



Channelization project in need of maintenance: concrete lining of White Oak Bayou, Houston, Texas, showing deterioration after few years of use. Human figure in middle-distance indicates scale.



This sea-wall along the New Jersey coast, by cutting into the ocean, redirects flooding patterns. Photo: Robert P. Martin, U.S. Bureau of Outdoor Recreation.



Channelization project in need of maintenance: concrete lining of White Oak Bayou, Houston, Texas, showing deterioration after few years of use. Human figure in middle-distance indicates scale. Photo: National Resources Defense Council.

the primary means of flood control.

Results are another valid basis for evaluating effectiveness. Regrettably, there are two obstacles to obtaining usable statistics and information about results. One is the scarcity of reliable, pertinent statistics; happily, this is slowly being remedied in some nations. Another is the difficulty of determining just who would return to live in the floodplain after a disaster — even if there were no flood-protection prospects. We know that many people want to return, especially after experiencing trauma; but others would leave if they did not have an investment to return to. Florence, Italy, has seen its flood-plain occupants turn over a dozen times in 500 years. Sikka (1973) indicates that the gravest flood damage in India's history, in 1971, was caused largely by reckless occupation of the flood-plain. But many of the victims of the 1972 flood at Wilkes-Barre, U.S.A., could have resettled on higher ground if governmental programmes had offered a practical choice.

Since 1937, the year of adoption of 'comprehensive' (actually structural) flood-control programme, the U.S. losses from flooding have apparently not been reduced — despite Federal expenditures of over \$12 thousand millions for structures and further great amounts for flood relief. The average annual amount of property damages has risen from \$350 millions in the nineteen-thirties to \$1,500-\$2,000 millions more recently (U.S. Office of Emergency Preparedness, 1972), and is increasing faster than applicable rates of inflation. The numbers of lives lost have decreased, on an average annual basis, but may now be on an upswing. The potential for major catastrophes has increased during this interim, in the view of many authorities (White *et al.*, 1975). In 1972, Hurricane Agnes hit areas of the Middle and North Atlantic drainage basins and the

upper Ohio, causing more damage (\$3 thousand millions) than any other single natural disaster in the history of the United States. The areas hit were the same ones that had been the subject of elaborate construction programmes.

These facts seem to indict the U.S. flood-control strategy, which relies on structures even today, although incentives for better land management are now coming into use. One might offer the rejoinder that disaster costs and potentials might have been greater without the strategy, but the experience of countries which rely more on land management suggests that the rejoinder is incorrect.

Structural methods require commitments of resources. Reservoirs require flooding of lands which are highly productive for farming, mining, and animal habitats. Channels tend to make streams sterile as regards fisheries and de-water the flood-plain (cf. Fig. 3), radically reducing the value of the stream and bank areas for conservation purposes (contrast Fig. 2). Sea-walls probably encourage occupation of estuarine wetlands, and to that extent reduce the potential of the oceans' and seas' food supply, while reducing the opportunities for recreation (cf. Fig. 5). Urban areas are deprived of valuable parks and open spaces which they badly need in cities, and which are so vital to human emotional and physical well-being.

Against these losses must be balanced the benefits of greater cropping and more intensive land occupancy which are made possible by structures. Moreover, the dams might have been built anyway — though perhaps with less capacity, since few dams are built solely for flood control. Thus many of those that are built for flood control are probably needed only to give short-term flooding relief — to buy time so that long-term land-management objectives can be attained.

The increased intensity of farming that is practised in many de-watered flood-plains requires an increase in the use of energy, and subjects the stream to increased pesticide and nutrient burdens. Therefore, the practice of intensifying farming in lowlands is at least questionable for many situations. As for land occupancy, it is rare indeed that intensive flood-plain settlement can be justified — for reasons that are given elsewhere in this paper; and as for a dam buying time to accomplish better land management downstream, the time is scarcely ever used. In fact, dams seem to be conducive to complacency, rigidifying existing land uses and stimulating insecure development in almost all instances. Correction of fundamental land misuses then generally becomes politically impossible — until the next occasion of flooding. At that time, rationality is difficult to achieve; we have learned through experience that most people in trauma apparently expect immediate action to deal with effects rather than with causes.

Regrettably we do not keep ledger sheets of benefits and losses of flood-control programmes, and so have to guess. Nevertheless it seems quite evident that, generally, the structural strategy is wasteful of resources — especially when one considers that land-management alternatives might often have been more effective than dams, even if dams would have been constructed anyway and have led to some positive benefit.

The most compelling case against the sole use of the structural strategy lies in the land-use argument, for, as a general guide, intensive use should usually not occur in the flood-plain, and moreover all the highly productive bank and shore areas are needed for conservation purposes. Thus, we do not require flood works which narrow the flood-way. Some industries that are dependent on water transportation may need to be situated in high-hazard

as, but they should be flood-proofed. It appears that most other industries can build on higher ground without serious ill effect on their function or economic position. Obviously, housing should not be sited in high-risk places, and usually monies spent to protect them will simply postpone disaster and make later reckoning more expensive.

Most settlements have enough land for building, so that they do not need to grow into extreme flood-hazard areas. This generalisation is, and will probably continue to be, true even for most communities in densely populated countries — until there is a radical breakthrough in food-growing technology or the development of highly stratified economic integration with other parts of the earth or with other planets.

On the other hand, flood-plains are ideal and highly productive for a wide range of conservation uses and for farming, mining, parklands, open spaces, human habitat, recreation, and other community activities. They are the site of the key links in many food-chains, and provide homes or transition space for numerous birds and other animals. They support a remarkable diversity of plant life, and contain some of the most suitable lands for wildlife conservation. Retaining the flood-risk areas as open lands is a wise investment for humans, helping to conserve high quality water and to achieve better noise control than is possible if stream banks are occupied.

There is wide disagreement about how much land should be set aside for conservation purposes, but the need in all countries probably exceeds the supply of flood-plains many times over. It therefore makes good sense to keep flood-plains open, as conservation uses generally thrive from floods and inasmuch as less suitable lands will need to be set aside for these uses anyway. If the flood-risk areas were devoted to conservation purposes, it would be unnecessary — usually even counter-productive — to protect them from floods.

Brower (1973) has suggested a method which can be used to reduce flood loss at minimum cost. He would use the least-energy principle, that is, the development which confronts as little water-energy as possible would be chosen. Thus, for flood control, the stream's natural bends and flood-plain would be used most often to absorb the energy of the water flow or waves, and direct

confrontation with the water's force would usually be avoided. The approach seems sound, and would help us to avoid use of the great quantities of man-made or pumped energy which are required for a structural approach to floods.

Some flood-control planners consider a proposed project cost-effective — that is, worthy — if the value of the average annual loss of structures in the flood-path before construction of control devices equals or exceeds the annual capitalised costs of construction and maintenance of these flood-control devices. Although other factors are now being considered in project evaluation, this cost-benefit approach is basic. The structural approach requires much of society's energy to fight the energy of the flood, and this all translates into money. The structure requires much direct and indirect energy to build and maintain. If it is not the correct answer, which it usually is not, then the energy drain continues for relief programmes and for another answer. Poorly conceived projects can thus eat at a society's capital, depriving other programmes of much-needed finance.

In the United States today, the average annual cost of flooding seems to be around \$3.5 thousand millions — including expenditures for structural construction and maintenance by all levels of government, insurance premiums, and private losses and reconstruction costs. The figure is going up, and if the current strategy continues, it may be as high as \$12 thousand millions annually by the year 2000. Inasmuch as the U.S. programme has been in operation for many years, the figure should be going down by now. It accordingly appears that the U.S. programme is not cost-effective; if it were, then after a period of time the losses should go down as total flood-control costs go up.

Thus it seems that the prospects of a structural programme decreasing flood losses are dim, as reduction in losses can occur only if almost all streams are diked and channelised and the shore is sea-walled. Moreover, the nation which devotes itself to structural remedies alone can expect a costly energy drain. If there were no alternatives, such a drain would be regrettable but tolerable, as the cause is good; but inasmuch as flood-plain management is a demonstrated, effective alternative, the drain is only regrettable.

The Political Answer

Too often, flood policies and programmes are based on the assumption that flood disasters result from Nature's actions, not Man's, whereas in actual fact the misery and damage are mostly caused by human error — especially by poor land management and myopic flood-control strategies.

In the United States, we are beginning to question the manner in which we approach flood-control planning, and there is every expectation that this questioning will become stronger and more frequent. Recently, many structural projects have been rejected, and flood-plain management alternatives have been selected in a few instances. In many cases, the answers have been chosen because of political activism by laymen. As with so many environmental problems, the solution is a political one rather than of a technological nature. Electors, tax-payers, and leaders, must insist on better results and accountability — or settle for expensive short-term answers and long-term disasters. Clearly, it is high time to reappraise structurally oriented programmes.

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Table 3.1.9 Tributary discharges direct to Lake Ontario and St. Lawrence River 1966-67 (short tons/year).

Tributaries Lake Ontario	Flow (cfs)	Population served (thousands)	BOD ₅	Total Solids	Susp.	Total nitrogen (N)	Total phosphorus (P)	Chlorides
Niagara River	195,000			42,800,000	5,030,000	95,300	7,700	5,200,000
North Niagara Peninsula and Niagara River Region								
Four Mile Creek	13*	-	56	3,030	688	59	3	38
(1) Welland Canal	1,230	17.4	2,490	350,000	56,000	1,120	116	42,400
(2) Twelve Mile Creek	6,400	3.0	44,500	1,810,000	217,000	7,670	587	180,000
Twenty Mile Creek	80	0.8	220	28,600	5,190	311	23	1,480
Forty Mile Creek	17	5.5	179	7,700	552	54	16	732
Northwestern Lake Ontario								
Redhill Creek	84	280	556	8,040	865	219	24	2,020
Spencer Creek	59	14.5	112	19,200	2,670	28	6	2,040
Grindstone Creek	26	1.3	55	10,400	2,260	38	2	548
Bronte Creek	119	-	73	15,000	2,200	94	4	747
Oakville Creek	88	13.4	240	23,100	3,430	280	11	2,140
Credit River	280	28.9	828	104,000	10,700	599	48	6,920
Stoney Creek	6.3	-	32	3,870	330	39	9	392
Metropolitan Toronto Region								
Mimico Creek	14.5	5.0	141	9,180	1,500	51	8	1,520
Etobicoke Creek	46*	51.5	93	12,400	357	134	25	596
Humber River	164	7.2	470	53,700	11,300	209	29	8,100
Don River	111	154	1,040	52,500	4,550	603	147	7,740
Highland Creek	25.3	108	63	9,060	808	102	39	1,62

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